Chemical
SAFETY AND SECURITY TRAINING

Personal Protective Equipment (PPE)

SAND No. 2009-8395P
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

Sandia National Laboratories

Limitations of PPE

- The least desirable control, but may be necessary if:
  - Engineering controls are being installed
  - Emergency response/spill cleanup
  - Non-routine equipment maintenance
  - To supplement other control methods
- Problems with PPE:
  - The hazard is still present with PPE
  - Use is very dependent on human behavior
  - Proper fitting is essential
- Can exposure be controlled by other means?

Personal Protective Equipment (PPE)

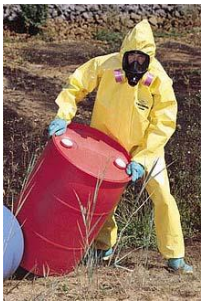
- Limitations of PPE
- Hazard assessment
- Training
- Characteristics of PPE
- Protective clothing
- Gloves
- Eyewear
- Respirators
- Exercise

PPE Hazard Assessment

- Identify the hazard(s)
  - Chemical
  - Mechanical
  - Electrical
  - Light energy (lasers, welding)
  - Fire response
  - Hot processes
- Identify the potential exposure route
  - Inhalation
  - Skin contact
  - Eye contact

PPE Hazard Assessment

- Identify the type of skin contact
  - Immersion
  - Spray
  - Splash
  - Mist
  - Vapor (gaseous)
- Consider the exposure time
  - Incidental contact
  - Continuous immersion
  - Unknown/emergency response



Training

Employees should be trained to know:

- When PPE is necessary
- What PPE is necessary
- How to properly don, doff, adjust and wear PPE
- Limitations of PPE
- Proper care, maintenance, useful life and disposal
- Involve workers in selection

http://www.free-training.com/OSHA/ppe/Ppemenu.htm

Exercise

- List one work activity at your plant that uses PPE
- What is the hazard?
- What is the route of exposure? Inhalation, skin, eyes, or ?
- Are there ways to control exposure to this hazard other than PPE?
  - What other ways?

Training

Retraining is necessary when there is:

- A change in the hazards
- A change in the type of PPE required
- Inadequate employee knowledge or use of PPE

http://www.free-training.com/OSHA/ppe/Ppemenu.htm

General Characteristics of PPE

Protective clothing and gloves:

- Act as a barrier to prevent contact with the skin
- Protect against
  - Toxics
  - Corrosives
  - Irritants
  - Sensitizers (allergens)
  - Thermal injury (burns)
  - Physical Trauma

Permeation Rate (PR)	Permeation Breakthrough (PB)	Permeation Degradation rate (DR)
E- Excellent; permeation rate of less than 0.9 mg/cm²/min	>Greater than (time - minutes)	E - Excellent; fluid has very little degrading effect.
VG - Very Good; permeation rate of less than 9 mg/cm²/min	< Less than (time - minutes)	G - Good; fluid has minor degrading effect.
G - Good; permeation rate of less than 90 mg/cm²/min		F - Fair; fluid has moderate degrading effect.
F - Fair; permeation rate of less than 900 mg/cm²/min		P - Poor; fluid has pronounced degrading effect.
P - Poor; permeation rate of less than 9000 mg/cm²/min		NR - Fluid is not recommended with this material.
NR - Not recommended; permeation rate greater than 9000 mg/cm²/min		† Not tested, but breakthrough time > 480 min DR expected to be Good to Excellent
		†† Not tested, but expected to be Good to Excellent based on similar tested materials

General Characteristics of PPE

Protective clothing and gloves

- When selecting consider:
  - Permeation
    - Breakthrough time
    - ASTM F739 Standard
  - Penetration
  - Degradation
  - Comfort
  - Heat stress
  - Ergonomics
  - Cost

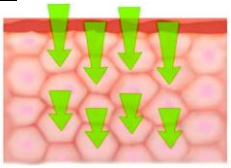


Photo credit: Permeation, http://www.cdc.gov/niosh/topics/skin/

Protective Clothing

- Special Applications
  - Hot processes
  - High voltage/arc flash
    - NFPA 70E
  - Foundries/molten metal
  - Refineries
- Select flame resistant clothing
- Chemical resistant coating may be added to flame resistant clothing

Gloves

- **Evaluate the work task**
  - **Chemical immersion or incidental contact?**
  - **Consider ergonomics/dexterity required**
- **Use glove charts**
  - **Charts recommend gloves for specific chemicals**
    - **Evaluate permeation rates and breakthrough time of selected glove for the specific task**
  - **Consider several glove manufactures data before final selection.**
    - http://www.mapaglove.com
    - http://www.ansellpro.com
    - http://www.bestglove.com/site/chemrest/

General Types of Glove Material

Laminated Gloves:4H®,Silver Shield®

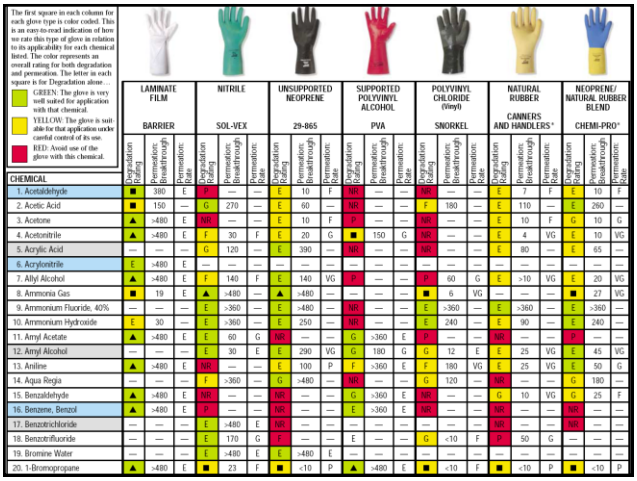
- Useful for a wide range of chemicals.

  NOT HYDROGEN FLUORIDE!

- Can use with a nitrile over glove to improve dexterity.

Butyl Rubber

- Highest permeation resistance to gas or water vapors.
- Uses: acids, formaldehyde, phenol, alcohols.



The first square in each column for each glove type is color coded. This is an easy-to-read indication of how we rate this type of glove in relation to its applicability for each chemical listed. The color represents an overall rating for both degradation and permeation. The letter in each square is for Degradation alone.:

GREEN: The glove is very well suited for application with that chemical.

YELLOW: The glove is suitable for that application under careful control of its use.

RED: Avoid use of the glove with this chemical.

CHEMICAL	LAMINATE FILM BARRIER			NITRILE SOL-VEX			UNSUPPORTED NEOPRENE 29-865			SUPPORTED POLYVINYL ALCOHOL PVA			POLYVINYL CHLORIDE (Vinyl) SNORKEL			NATURAL RUBBER CANNERS AND HANDLERS*			NEOPRENE/ NATURAL RUBBER BLEND CHEMI-PRO*		
	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate
1. Acetaldehyde	■	380	F	P	—	—	E	10	F	NR	—	—	NR	—	—	E	7	F	E	10	F
2. Acetic Acid	■	150	—	G	270	—	E	60	—	NR	—	—	F	180	—	E	110	—	E	260	—
3. Acetone	▲	>480	E	NR	—	—	E	10	F	P	—	—	NR	—	—	E	10	F	G	10	G
4. Acetonitrile	▲	>480	E	F	30	F	E	20	G	■	150	G	NR	—	—	E	4	VG	E	10	VG
5. Acrylic Acid	—	—	—	G	120	—	E	390	—	NR	—	—	NR	—	—	E	80	—	E	65	—
6. Acrylonitrile	E	>480	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7. Allyl Alcohol	▲	>480	E	F	140	F	E	140	VG	P	—	—	P	60	G	E	>10	VG	E	20	VG
8. Ammonia Gas	■	19	E	▲	>480	—	▲	>480	—	—	—	—	■	6	VG	—	—	—	■	27	VG
9. Ammonium Fluoride, 40%	—	—	—	E	>360	—	E	>480	—	NR	—	—	E	>360	—	E	>360	—	E	>360	—
10. Ammonium Hydroxide	E	30	—	E	>360	—	E	250	—	NR	—	—	E	240	—	E	90	—	E	240	—
11. Amyl Acetate	▲	>480	E	E	60	G	NR	—	—	G	>360	E	P	—	—	NR	—	—	P	—	—
12. Amyl Alcohol	—	—	—	E	30	E	E	290	VG	G	180	G	G	12	E	E	25	VG	E	45	VG
13. Aniline	▲	>480	E	NR	—	—	E	100	P	F	>360	E	F	180	VG	E	25	VG	E	50	G
14. Aqua Regia	—	—	—	F	>360	—	G	>480	—	NR	—	—	G	120	—	NR	—	—	G	180	—
15. Benzaldehyde	▲	>480	E	NR	—	—	NR	—	—	G	>360	E	NR	—	—	G	10	VG	G	25	F
16. Benzene, Benzol	▲	>480	E	P	—	—	NR	—	—	E	>360	E	NR	—	—	NR	—	—	NR	—	—
17. Benzotrichloride	—	—	—	E	>480	E	NR	—	—	—	—	—	—	—	—	NR	—	—	NR	—	—
18. Benzotrifluoride	—	—	—	E	170	G	F	—	—	E	—	—	G	<10	F	P	50	G	—	—	—
19. Bromine Water	—	—	—	E	>480	E	E	>480	E	—	—	—	—	—	—	—	—	—	—	—	—
20. 1-Bromopropane	▲	>480	E	■	23	F	■	<10	P	▲	>480	E	■	<10	F	■	<10	P	■	<10	P

Types of Gloves

Neoprene

- Protects against acids, caustics.
- Resists alcohols, glycols.

Nitrile

- Good replacement for latex
- Protects against acids, bases, oils, aliphatic hydrocarbon solvents and esters, grease, fats
- NOT ketones
- Resists cuts, snags, punctures and abrasions

Latex Allergy

Eye and Face Protection

- **Each day, 2000 U.S. workers have a job-related eye injury that requires medical treatment.**
- **Nearly *three out of five* U.S. workers are injured while failing to wear eye and face protection.**

NIOSH. (2010). http://www.cdc.gov/niosh/topics/eye/

Proper Steps for Removing Gloves

1

2

3

4

5

6

Types of Eye Hazards

Hazard Type	Common related tasks	Protective Eyewear
Impact	Chipping, grinding, machining, abrasive blasting, sawing, drilling, riveting, sanding,…	Safety glasses with sideshields Goggles
Heat	Furnace operations, smelting, pouring, casting, hot dipping, welding, …	Face shield with infrared protection
Chemicals	Pouring, spraying, transferring, dipping acids, solvents or other injurious chemicals	Goggles Faceshield
Particles/ Dust	Woodworking, metal working, and general dusty conditions	Safety glasses with sideshields
Optical Radiation	Welding, torch-cutting, brazing, and laser work	Welding helmet Laser glasses -Must protect for specific wavelength of ultraviolet or infrared radiation.

Examples of Eye & Face Protection

- Goggles
- Face shield
- Safety glasses
- Welding helmet
- Hooded faceshield

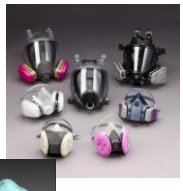
Basic Types of Respirators

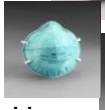
- Air purifying (APR)
  - Half Face
  - Full Face
  - Powered APR (PAPR)
- Air supply
  - Air line
  - SCBA

Respiratory Protection

U.S. Respirator Requirements

- Written program
- Hazard assessment
  - Air monitoring
- Medical clearance
- Fit testing
- Respirator selection
- Procedures
  - Cleaning, maintenance, repairing
- Training (annual refresher)





Air Purifying Respirators (APR)

- Work area must have at least 19.5% oxygen
- The contaminant must have adequate warning properties. Ex. ammonia
  - Never use APR in oxygen deficient atmospheres
- APRs work by filtering, absorbing, adsorbing the contaminant or chemical reaction.
  - Filters, cartridges, canisters
- The contaminant concentration must NOT exceed the maximum use concentration.
- Some cartridges have “end of service life” indicators or can use change schedules

Types of APR Cartridges

Cartridge	Description
	**Organic Vapor**
	**Organic Vapor and acid gases**
	**Ammonia, methylamine and P100 particulates filter**

APR Filter Efficiency

National Institute of Occupational Safety and Health
Filter Efficiencies

Filter Class	
N95	Filters at least 95% of airborne particles. Not resistant to oil.
N99	Filters at least 99% of airborne particles. Not resistant to oil.
N100	Filters at least 99.97% of airborne particles. Not resistant to oil.
R95	Filters at least 95% of airborne particles. Somewhat resistant to oil.
P95	Filters at least 95% of airborne particles. Strongly resistant to oil.
P99	Filters at least 99% of airborne particles. Strongly resistant to oil.
P100	Filters at least 99.97% of airborne particles. Strongly resistant to oil

End of Service Life Indicators (ESLI)

There are very few NIOSH-approved ESLI's:

- ammonia
- carbon monoxide
- ethylene oxide
- hydrogen chloride
- hydrogen fluoride
- hydrogen sulfide
- mercury
- sulfur dioxide
- toluene-2,4-diisocyanate
- vinyl chloride

Assigned Protection Factors (APF)

- **Level of workplace respiratory protection that a respirator or class of respirators is expected to provide.**
- **Each specific *type* of respirator has an Assigned Protection Factor (APF).**
- **Select respirator based on the exposure limit of a contaminant and the level in the workplace.**

Maximum Use Concentration (MUC)

= APF x Occupational Exposure Limit (e.g. PEL, TLV)

Assigned Protection Factors

Type of Respirator	Half Face Mask	Full Facepiece	Helmet/ Hood	Loose-Fitting Facepiece
Air-Purifying	10	50	-	-
PAPR	50	1,000	25/1,000	25
Supplied-Air or Airline				
– Demand	10	50	-	-
– Continuous flow	50	1,000	25/1000	25
– Pressure demand	50	1,000	-	-
SCBA				
– Demand	10	50	50	-
– Pressure Demand	-	10,000	10,000	-

Filtering Facepieces

Assigned Protection Factors

Workplace air sampling indicates the exposure to benzene is 15 ppm. The exposure limit is 0.5 ppm (ACGIH TLV). What respirator should you choose?

Maximum Use Concentration (MUC) = APF x OEL

Half Face Mask: MUC = 10 x 0.5 ppm = 5 ppm

PAPR (LFF): MUC = 25 x 0.5 ppm = 12.5 ppm

Full Face Respirator: MUC = 50 x 0.5 ppm = 25 ppm

Filtering Facepiece Use

Respirator Fit Testing

- Qualitative
  - Irritant smoke
    - stannic chloride
  - Isoamyl acetate
    - banana oil
  - Saccharin
  - Bitrex
- Quantitative
  - Portacount

Supplied Air

- Supplies breathing air to worker
  - SCBA
  - Airline
- Must use Grade D Air
- Many limitations

Respirator Fit Test

Positive / Negative pressure fit test

Breathing Air Quality and Use

- Compressed breathing air must be at least Type 1 - Grade D [ANSI/CGA G-7.1-1989]:
  - Oxygen content = 19.5 - 23.5%
  - Hydrocarbon (condensed) = 5 milligrams/cubic meter or less
  - CO ≤ 10 parts per million (ppm) or less
  - CO_2 of 1,000 parts per million (ppm) or less
  - Lack of noticeable odor
- Compressors may be equipped with in-line air-purifying sorbent beds and filters.

Maintenance and Storage Procedures

- **Disposable filtering face-piece:**
  - Dispose after use
- **Air purifying respirators:**
  - Discard cartridges based on expiration date, end-of-service life indicator or calculated service life
  - Clean
  - Dry
  - Place in sealable bag (write your name on bag)
  - Contact Safety Office for repairs
- **SCBA:**
  - Inspected monthly
  - Accessible and clearly marked

Foot Protection

Types:

- **Impact, penetration, compression, steel toe, etc.**
- **Non-skid, with slip resistant soles.**
- **Chemical resistant** (rubber, vinyl, plastic, with synthetic stitching to resist chemical penetration).
- **Anti-static**
- **Temperature resistant (high or low extremes).**
- **Electrical protection (non-conducting).**
- **Water resistant**

Exercise

- **A contractor has been hired to sweep out a work area that contains lead dust. The plant safety officer has recommended that the worker don a full-face air purifying respirator with a HEPA filter (P100) during this activity.**
- **Later that week the plant safety officer observes the worker sweeping without wearing the respirator. When asked why he is not wearing the respirator, the worker states "it is too uncomfortable to wear."**
- **What approach should the safety officer take to ensure the worker wears a respirator?**

Head Protection

Should meet or exceed Z89.1-2003

Types:

- **Bump caps - don't meet ANSI standard, provide minor protection**
- **Electrical protection to 2200-22,000 volts**
- **Mining protection**
- **Classic-- high impact general purpose protection.**
- **Impact 386 – 454 kilograms**
- **Penetration ~1centimeter**

PPE Exercise

- Worker A needs to transfer 10 liters of acetone into a hazardous waste drum.
- The safety officer has determined that due to the use of ventilation, the air concentration of acetone is below the exposure limit.
- The worker may have incidental skin contact with the acetone during pouring.
- Prolonged skin exposure to acetone causes dry and cracked skin, but acetone is not normally absorbed through the skin.
- There is also a possibility that the acetone may splash in the worker's face during pouring.

PPE Exercise

- Worker C is tasked with adding zinc oxide pigment into a mixing bath by hand.
- This task will take 15 minutes.
- Worker C performs this task once every day.
- The safety officer has determined that the airborne concentration during this task is 20 milligrams/cubic meter.
- The short term exposure limit (15 minutes) for zinc oxide is 10 milligrams/cubic meter .
- Zinc oxide powder is mildly irritating to the skin and eyes, but not toxic or corrosive.

What PPE should Worker C wear?

PPE Exercise

- Worker B is walking back from the break room when he notices a yellow cloud of chlorine coming towards him from the chlorine storage area. He also notices that some of the chlorine has come into contact with water under one of the tanks and formed chlorine hydrate.
- He alerts the emergency response team who arrive at the emergency staging area.
  - Chlorine is a corrosive and toxic gas by inhalation.
  - Chlorine hydrate is corrosive to the skin and eyes.
  - The airborne concentration of chlorine is unknown in this situation.

What PPE should the emergency response team use?

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Industrial Ventilation

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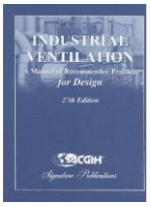
Industrial Ventilation

- Definitions
- Common Terminology
- Purpose
- Hazard Assessment
- General Ventilation
- Local Exhaust Ventilation
- Ventilation Evaluation
- Troubleshooting
- Exercises



American Conference of Governmental Industrial Hygienists (ACGIH) Ventilation Manual 27th Edition http://www.acgih.org/store/ProductDetail.cfm?id=1905

Common Terminology

Q = volume of air in cubic meters

V = velocity of air in meters per second

- **Duct velocity-velocity required to transport the contaminant**
- **Face velocity-velocity on the front of an enclosing hood**
- **Capture velocity-velocity required to capture contaminant at point of generation**

A = cross sectional area of hood opening in square meters

X = distance of ventilation from the source in meters

Definitions

- **Heating, ventilating and air conditioning** (**HVAC**):refers to the distribution system for heating, ventilating, cooling, dehumidifying and cleansing air.
- **Replacement/Supply air:** refers to replacement air for **HVAC** and local exhaust ventilation.
- **General ventilation:** refers to ventilation that controls the air environment by removing and replacing contaminated air before chemical concentrations reach unacceptable levels.
- **Local exhaust ventilation (LEV):** refers to systems designed to enclose, or capture and remove contaminated air at the source.

Purposes of Industrial Ventilation

- **Protect workers from health hazards**
  - ***Dilute, capture, or contain*** **contaminants**
- **Protect workers from hot processes**
  - ***Ovens, foundries***
- **Protect the product**
  - ***Semiconductor***
  - ***Electronics***
  - ***Pharmaceuticals***

Slot Hood

Canopy Hood

Laboratory Fume Hood

Purposes of Industrial Ventilation

- Emergency ventilation
  - Standalone fans
  - Detectors connected to ventilation or scrubber systems
  - Safe room
    - Positive pressure
- Enclosed vented rooms or cabinets
  - Gas cabinets
- Comply with health and safety regulations

Photo credit: Emergency Responder Products

Photo credit: Advanced Specialty Gas Equipment

General Ventilation

- Natural Ventilation:
  - Useful for hot processes
  - Chimney effect
  - Windows and doors kept open
- Example: a warehouse opens the windows to create natural ventilation

  Q = 0.2 AV

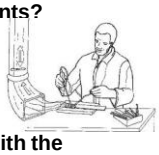
  A = square meters (area of open doors)

  V = wind speed in kilometers/hour

  Q = estimates the flow rate through the building (m/s)

Hazard Assessment

- What are the airborne contaminants?
  - Particles
  - Solvent vapors
  - Acid mists
  - Metal fumes



- How do to the workers interact with the source contaminant?
- Are workers exposed to air contaminants in concentrations over an exposure limit?

  *Requires air monitoring of the task
- Dilution or local exhaust ventilation?

Picture Credit : International Labor Organization

General Ventilation

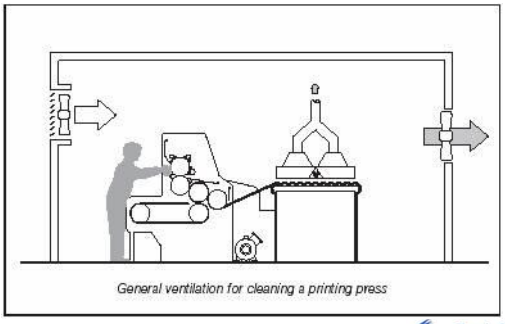
Dilution Ventilation

- Heat control
- Dilution of odors, flammables
- Not for control of toxics

Principles

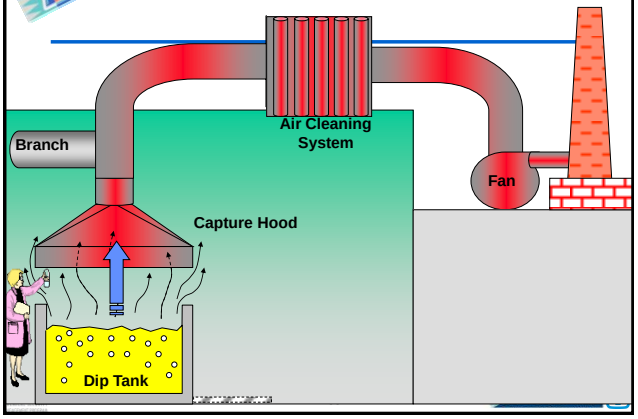
- Contaminant emissions must be widely dispersed
- Exhaust openings must be near contaminant source
- The worker must not be downstream of contaminant
- Air flow over worker should not exceed 3.5 meters/sec

General Ventilation



General ventilation for cleaning a printing press

Local Exhaust Ventilation

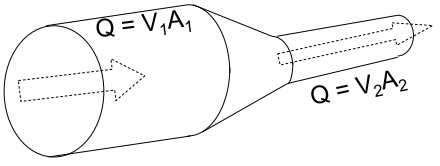


Local Exhaust Ventilation (LEV)

- **Use when contaminant concentration cannot be controlled by dilution ventilation or other controls**
- **Select the type of LEV from hazard assessment**
  - **Which type is best to capture the contaminant?**
    - **Enclosed or capture hood?**
    - **Consider worker's needs**
  - **What duct transport velocity is required to carry the contaminant? Heavy particles?**
  - **What face or capture velocity is required?**
- **Select duct material for the contaminant**
- **Ensure enough replacement air/adequate fan size**

Local Exhaust Ventilation

Volumetric Flow Rate, Q = VA [**Circular Opening**]

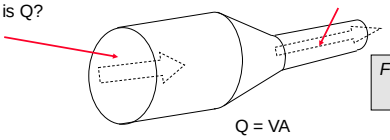


Q = Volumetric flow rate, in cubic meters/second
V = Average velocity, in meters/second
A = Cross-sectional area in square meters

Local Exhaust Ventilation

Duct diameter = 1 meter
V = 600 meters/second
What is Q?

Duct diameter = 0.5 meter
What is the duct velocity (V)?



For circular ducts
$A = \pi\ d^2/4$

Q = VA

Q = (600 m/s)(π[1m]^2/4)

Q = **471 meters^3/second**

Q = VA

471 meters^3/s = V (π[0.5m]^2/4)

V = 2400 meters/second

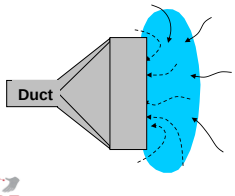
HOOD TYPE	DESCRIPTION	ASPECT RATIO, W/L	AIR FLOW
	SLOT	0.2 OR LESS	Q = 3.7 LVX
	FLANGED SLOT	0.2 OR LESS	Q = 2.6 LVX
	PLAIN OPENING	0.2 OR GREATER AND ROUND	Q = V(10X^2+A)
	FLANGED OPENING	0.2 OR GREATER AND ROUND	Q = 0.75V(10X^2+A)
	BOOTH	TO SUIT WORK	Q = VA = VWH
	CANOPY	TO SUIT WORK	Q = 1.4 PVD SEE FIG. VS-99-03 P = PERIMETER D = HEIGHT ABOVE WORK
	PLAIN MULTIPLE SLOT OPENING 2 OR MORE SLOTS	0.2 OR GREATER	Q = V(10X^2+A)
	FLANGED MULTIPLE SLOT OPENING 2 OR MORE SLOTS	0.2 OR GREATER	Q = 0.75V(10X^2+A)

ACGIH Ventilation Manual

Local Exhaust Ventilation

D = DUCT DIAMETER

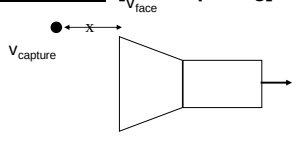
JET V_{face} **30 Duct Diameters**



Capture of contaminant is only effective within <u>one (1) duct diameter</u>

Local Exhaust Ventilation

<u>Capture Velocity (V)</u> : [Plain Opening]



Q = V (10x^2 + A)
X = distance of source from hood face

Recommended Capture Velocities

CONDITION	EXAMPLES	CAPTURE VELOCITY Range in meters/second
No velocity, Quiet air	Evaporation from tanks, degreasers	0.25 – 0.5
Low velocity, moderately still air	Spray booths, container filling, welding, plating	0.5 – 1.0
Active generation into rapid air motion	Spray painting (shallow booths), crushers	1.0 – 2.5
High initial velocity into very rapid air motion	Grinding, abrasive blasting, tumbling	2.5 – 10.1

ACGIH Ventilation Manual

Local Exhaust Ventilation

- **Canopy hood:**
  - Best for controlling hot processes
  - Not good for capturing dusts, or vapors
  - Not good where cross-drafts exist
  - Worker must not put head under canopy

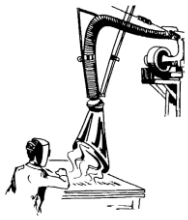
Recommended Duct Velocities

CONTAMINANT	EXAMPLES	DUCT VELOCITY Meters/second
Vapors, gases, smoke	Vapors, gases, smoke	5.0 – 10.1
Fumes	Welding	10.1 – 12.7
Very fine dust	Cotton lint	12.7 – 15.2
Dry dusts & powders	Cotton dust	15.2 – 20.3
Industrial dust	Grinding dust, limestone dust	17.8 – 20.3
Heavy dust	Sawdust, metal turnings	20.3 – 22.9
Heavy/moist dusts	Lead dusts, cement dust	> 22.9

ACGIH Ventilation Manual

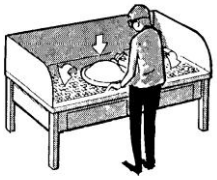
Local Exhaust Ventilation

- **"Elephant trunk":**
  - Good for welding fumes, small process tasks, machining, disconnecting process lines
  - Place close to contaminant
  - Ensure adequate capture velocity at distance from contaminant
  - *Flanged* opening captures contaminant better



Local Exhaust Ventilation

- **Downdraft hood:**
  - Vapors pulled down through grill
  - Capture velocity depends on source distance from grill
  - Not for hot operations

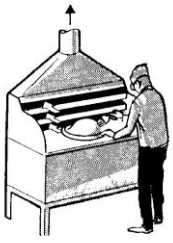


Local Exhaust Ventilation

- **Fume hood:**
  - Laboratory use
  - Best for small amounts of chemicals
  - Sash must be kept at set level
  - NO storage of equipment in the hood!

Local Exhaust Ventilation

- **Slot ventilation:**
  - Best for liquid open surface tanks
    - Acid baths
    - Plating tanks
  - Pulls air across the tank away from worker
  - Side enclosures prevent cross drafts
  - Push-Pull design is optional (push jet)



Local Exhaust Ventilation

- **Enclosures:**
  - Example:
    - Paint booths
  - Control of exposure to liquid aerosols and vapors
  - Flammability hazard
  - Must have scheduled filter changeout
  - Operator must be upstream

Photo Credit: Spray Shield Industries

Local Exhaust Ventilation

- **Other vented enclosures**
  - Glove boxes
  - Furnaces/ovens
  - Abrasive blasting

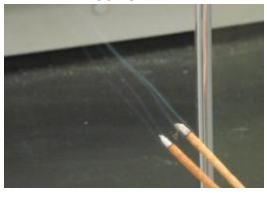
Photo credit: Borel Furnaces and Ovens

Photo credit: U. S. Department of Labor. OSHA

Ventilation System Evaluation

- Evaluate capture velocity
  - Quantitatively-anemometers, velometers
  - Qualitatively-smoke tubes,
    - Visualizes air movement
    - Use water vapor for clean rooms

Photo Credit: All Products Inc.



Local Exhaust Ventilation

Exhaust Systems:

- Do not place exhaust stack near air intakes
  - –Re-entrains contaminants into the building
- Do not use rain caps
- Stack height depends on:
  - –Contaminant temperature
  - –Building height
  - –Atmospheric conditions
  - –Discharge velocity
  - –Ideal discharge velocity is **15 meters per second**

Ventilation System Evaluation

- Air velocity measurements
  - Measure air velocities (meter/sec) at a number of points
  - Average the results and determine volumetric flow rate: Q = VA
  - All instruments must be calibrated periodically
  - Types:
    - Swinging vane velometer
    - Hot-wire anemometer

Troubleshooting

- Wrong hood for process
  - Example: canopy hood for toxics
- Insufficient capture velocity
- Insufficient duct velocity
  - ~14 meters/second for vapors
  - ~18 meters/second for dust
- Too much air flow = turbulence
- Traffic or competing air currents
- Insufficient make up air
  - Negative pressure
  - Can't open doors

Exercise

- What is the preferred ventilation system for the following situation?
  - Acid processing bath with open surface area

A) Lab fume hood
B) Slot ventilation
C) Elephant trunk
D) Canopy hood
E) Paint booth

Exercise

- What is the preferred ventilation system for the following situation?
  - Dilute non-toxic odors in the warehouse

A) General ventilation
B) Local exhaust ventilation

Exercise

- What is the preferred ventilation system for the following situation?
  - Welding table

A) Lab fume hood
B) Slot ventilation
C) Elephant trunk
D) Canopy hood
E) Paint booth

Exercise

- What is the preferred ventilation system for the following situation?
  - Chemical analysis of small samples for quality control

A) Lab fume hood
B) Slot ventilation
C) Elephant trunk
D) Canopy hood
E) Paint booth

US Standards & Guidelines

ACGIH
American Conference of Governmental Industrial Hygienists
Industrial Ventilation, A Manual of Recommended Practice

AIHA
American Industrial Hygiene Association
Standard Z9.2, Fundamentals Governing the Design and Operation of Local Exhaust Ventilation Systems

ASHRAE
American Society of Heating, Refrigeration and Air Conditioning Engineers
Standard 62.1-2010, Ventilation for Acceptable Indoor Air Quality

OSHA
Occupational Safety and Health Administration
Ventilation, 29 Code of Federal Regulations 1910.94
http://osha.gov/

Exercise

- What is the preferred ventilation system for the following situation?
  - Spray painting a large piece of equipment

A) Lab fume hood
B) Slot ventilation
C) Elephant trunk
D) Canopy hood
E) Paint booth